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PEANUT PROTEIN FIBER: ITS POSITION IN THE PROTEIN FIBER WORLD [1]

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During the past 10 years so many different types of synthetic fibers have been produced, both in the laboratory and on a commercial scale, that attempts to select suitable generic names for them have often lagged far behind the progress of the art itself. Each time some semblance of order was attained, a new type of fiber would make its appearance which fitted into none of the existing categories.

When "Lanital," a casein-base fiber, was commercially developed in Italy about 1935, it could not correctly be classified as a type of rayon and it was known at first as artificial wool, milk wool, etc. Since then, synthetic fibers of this same type have been produced from many other raw materials such as soybeans, peanuts, corn, egg white, feathers, and fish albumin. The base of all these fibers is protein and they are now referred to technically as synthetic, or man-made protein fibers, in distinction to the natural protein fibers, such as wool, mohair, and silk.

In an attempt to establish a suitable generic name for protein-base synthetic fibers, Committee D-13 of the ASTM has recently recommended the name azlon (A-Z-L-O-N). Although this name has not yet gained widespread use, it is intended to be comparable to the word "rayon" which, as you know, is used to designate all cellulose-base synthetic fibers.

Following the commercial introduction of Lanital in Italy, the production of casein-base fibers was soon extended to other European countries, and in 1941, the commercial production of a casein-base fiber known as Aralac was begun in the United States. About the same time, pilot plant production was started on a protein fiber made from soybeans, and it has been reported that plans are now under way for the commercial production of this fiber. Semi-commercial production has taken place in England on a fiber made from the protein derived from peanuts. This fiber has been given the trade name of Ardil. All other types of protein-base synthetic fibers have so far been produced only on a laboratory or small pilot-plant scale. Laboratory research is being conducted on casein fibers at the Eastern Regional Research Laboratory, on zein or corn protein fibers at the Northern Laboratory, and on fibers made from the protein in chicken feathers at the Western Laboratory.

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Most of those working in the field of synthetic, protein-base fibers consider the product to be at the same stage of development as was rayon about 30 years ago. The fibers are comparatively weak, especially in regard to their wet strength, and are in general used in textiles only when blended with other fibers. From a technical standpoint, however, the industry would seem to be potentially in a much more advantageous position than rayon was in the early days, because in the production of synthetic fibers there are many technical problems common to all types, and those working with protein-base fibers have a mass of accumulated knowledge and techniques from which to draw in their research and development work. No one, of course, can predict what the eventual outcome will be, but it is a fact that definite progress is being made today in improving the properties of synthetic protein fibers.

Peanuts are one of the farm commodities which were assigned to the Southern Regional Research Laboratory for research on the development of new and extended industrial outlets for farm commodities, so it was natural that the production of fiber from peanut protein should be one of the projects selected for study. Research on the production of a satisfactory synthetic fiber from peanuts is part of an overall project whose objective it is to develop industrial products, such as adhesives, sizes, paper coatings, cold water paints, etc., from the protein obtained from peanuts. Similar products can be made from soybean protein and from casein, but the production problems are somewhat different for each of these raw materials and the resultant products have various advantages and disadvantages.

In the development of a peanut protein fiber, the first problem encountered was the presence of coloring matter in the skins of the peanuts. If not removed, this coloring matter carries through into the finished product. Removal of the skins by the blanching process generally employed by the food industries is costly and is usually accomplished at temperatures so high as to damage the protein for use in fibers. It was found that this problem could be overcome by washing the kernels in a dilute lye solution, rinsing, and drying to the required moisture content. Total costs for decolorizing and drying, including amortization of equipment, labor, and alkali, are nominal and are estimated at less than one-tenth of a cent per pound of peanuts. Mechanical methods for removing the colored skins are also receiving attention, and if they can be worked out economically may be adopted commercially as a substitute for the above chemical treatment.

The major problem is that of obtaining an oil-free meal from which a satisfactory protein could be extracted. Practically all of the peanut meal produced in this country is now obtained by the hydraulic press or screw-press processes. Meal produced by these processes is unsatisfactory for two reasons: first, the residual oil left in the meal is so high as to cause trouble in the protein extraction process, and second, the high temperature used in these processes damages the protein for use in fibers, and for most other industrial uses. The solvent extraction process, however, gives an entirely satisfactory, low oil content meal. As a consequence, the Southern Regional Research Laboratory has used the solvent extraction process in all of its work on the industrial utilization of peanut protein. The solvent extraction process is coming into wider use in the soybean industry, and is being introduced this year for processing cottonseed. I will have more to say later on about the importance of this development.

Solvent-extracted peanut meal contains about 50 percent protein. In the process developed at the Southern Regional Laboratory, about 33 pounds of protein are obtained for each 100 pounds of meal processed. After the protein is extracted, the remainder consists of about 42 pounds of meal residue, having a feed value equal to about 33 pounds of the original meal, and a supernatant liquid containing about 16 pounds of solids in the form of minor soluble protein components, non-protein nitrogen, carbohydrates, minerals, and other non-protein materials present in the original meal. The supernatant liquor can be converted into an excellent medium for yeast propagation in the production of feed yeasts. In our laboratory experiments, there was an overall processing loss of 9 pounds, which can probably be reduced in larger scale operation.

The preparation of the protein itself is simple, consisting of extraction of the protein from the oil-free meal by means of dilute alkali, and precipitation of the extracted protein followed by drying.

I do not think you would be particularly interested in the details of this protein extraction process, but I do want to point out that the various steps must be carefully controlled with regard to the temperature and pH. If the extraction process is not properly carried out, only inferior fibers can be produced from the isolated protein.

The equipment used in the production of fibers from peanut protein is similar to that used in the production of rayon, and the processing itself is somewhat similar, except that different chemicals are used in the preparation of the spinning solutions and in the treatments used on the spun fibers. It is in these processes that research is centered in an effort to improve the quality of peanut protein fibers.

Essentially, the production of fibers from peanut protein involves the following steps: (1) Dispersion of the peanut protein in strong alkali to form a spinning solution; (2) Extrusion of the spinning solution through a spinnerette into an acid coagulating bath; and (3) Stretching and chemically treating the fibers to give them the desired properties.

Protein molecules as they occur in peanuts are generally considered to have a globular, coiled structure, which they retain after the usual extraction and purification processes. In a somewhat over-simplified statement of the problem, the object is to uncoil and orient the protein molecules in the direction of the fiber filament, and stabilize their orientation by interaction between adjacent groups in the parallel-oriented molecular chains. This is the structure of the natural protein fibers, such as silk and wool, and the process is similar to that already achieved in the production of high-tenacity rayon, nylon, and other high-strength synthetic fibers. In the production of high-tenacity rayon, it has been found possible to accomplish this by stretching the rayon filaments while they are in a plastic state, but, so far, high orientation of peanut protein molecules has not been achieved by this comparatively simple process. If synthetic protein-base fibers are ever to be produced with strength and other properties comparable to those of the natural protein fibers, it is believed that more molecular orientation than is obtained now will have to be effected.

In the production of peanut protein fibers at the Southern Regional Research Laboratory the spinning solutions are usually prepared with a protein concentration of from 18 to 24 percent. At this stage, various oils, emulsifiers, and plasticizers are added as desired and any entrapped air or other gas removed by centrifuging. Best results to date have been obtained with a spinning solution containing dibutyl tartrate, diglycol laurate, and peanut oil, adjusted to a pH of approximately 12.0 with a 2.4 N. solution of sodium hydroxide.

After aging a short time, the spinning solution is pumped through a spinnerette into a coagulating bath containing sulfuric acid, sodium sulfate, and dextrose. If the yarn is washed and dried at this stage, it becomes hard and brittle, crumbling into powder upon handling. Instead, the yarn is given a series of stretching and curing treatments which gives it properties suitable for handling on standard textile machinery. The process now used consists of subjecting the yarn to a low stretch (about 15 percent) as it goes through the coagulating bath, followed by two successive stretches of approximately 100 percent and 150 percent each, resulting in an over-all stretch of about 470 percent. During each of these latter two stretches, the yarn is washed with aqueous curing solutions of formaldehyde, sodium sulfate, and aluminum sulfate, the first solution containing also a small percentage of sulfuric acid. After the final stretch, the yarn is wound onto a bobbin with very low tension and given a final curing treatment, usually in an aqueous acid solution containing halide ions, metal ions, and formaldehyde. The yarn is then washed and dried and is ready for textile processing.

Peanut protein fiber produced in our laboratory according to the foregoing process has been given the name of Sarelon. Sarelon is a light-cream-colored fiber with a soft, pleasant hand intermediate between that of silk and wool. Upon contact with the skin it has a warm feel, and it absorbs moisture in a manner similar to wool. Since the yarn is relaxed when removed from the spin-bobbin, it has a high degree of dimensional stability and does not shrink appreciably in hot water. Peanut Protein fiber has an affinity for dyes normally used on natural protein fibers, but the rate of dye absorption is greater than on wool. Solid shades may be obtained by dyeing wool and Sarelon unions with a level-dyeing acid dye from a boiling dye bath containing Glauber's salt and acid. Sarelon may be successfully dyed with vat and direct cotton dyes; this characteristic makes possible, by the selection of suitable dyes, the production of a cellulose and peanut-protein-fiber union having solid shades.

In regard to physical properties, Sarelon has approximately the same wet and dry strengths as fibers made from casein and soybean protein; that is, dry strengths up to about 0.9 grams-per-denier, and wet strengths up to about 0.4 grams-per-denier. The principal deficiency of Sarelon for use in ordinary textiles is its low wet strength, a characteristic of all present types of synthetic protein fibers. The dry strength, also, is lower than wool, which has a strength of 1.0 to 1.5 grams-per-denier, and much lower than rayon, silk, and cotton, which have strengths ranging from 2.0 to 6.0 grams-per-denier. Low elongation at low loads and low recoverable elongation at high loads are also undesirable properties of present types of synthetic protein fibers. As a consequence, these fibers have only a very limited use by themselves in standard textile fabrics, but they can be used in blends with other fibers to give fabrics of adequate strength which possess properties not obtainable with these other fibers, or, in the case of wool, obtainable only at higher cost. Considerable quantities of casein-base fibers have also been used with fur in the manufacture of hat felts and similar products.

You will note here a very close parallel to the early history of rayon, when it was possible to make a satisfactory fabric with it only in blends with yarns made from other fibers. Used first as a cheap imitation of silk, rayon has now been developed to the point where it is recognized as having distinct and useful properties of its own.

In 1920, United States' production of rayon was 10 million pounds, about the same as the reported domestic production of synthetic protein fibers today. As the properties of rayon were improved and its production expanded, the problem of suitable and adequate sources of cellulose became a major consideration. Cellulose for rayon is now being obtained from several different species of trees and from cotton linters. Even with synthetic protein fibers in their present stage of development, suitable and adequate sources of protein are becoming problems of major consideration. As in the case with rayon, it is probable that more than one major source of raw material will be used in the production of these fibers. When viewed from this standpoint, it is very likely that economic considerations will be of equal importance with technical considerations in determining the future relative importance of peanut protein fibers in the protein fiber field. For this reason, it will be well to review some of the factors involved.

All of the present and potential sources of industrial protein in this country have one feature in common, namely, the protein available from these sources is obtainable only from byproducts whose value is much less than that of the principal products. For this reason, the potential supply of industrial protein from any one source is largely limited by the demand for the principal products. Furthermore, users of industrial protein will have to compete either directly or indirectly with consumers of these byproducts from which the protein is obtained. Lastly, the protein fiber industry will have to compete directly with other users of industrial protein, of which there are many.

Casein is the largest present source of protein used in the commercial manufacture of fibers. As you know, casein is obtained from skimmed milk and the potential supply of casein is therefore dependent upon the quantity of skimmed milk produced. On this basis, there is potential supply of casein of about 500 thousand tons annually from skimmed milk not used for human food or in other high-grade outlets, but the present available supply is much less than that. Most of the skimmed milk produced in this country is produced and used on farms, although in recent years farmers have been bringing more and more of their whole milk to centralized milk plants. Present supplies of casein are obtained from the skimmed milk produced in commercial creameries, most of which is manufactured into food products. In recent pre-war years domestic production of casein averaged about 20 to 25 thousand tons, which was supplemented by imports to give an average supply of about 30 thousand tons. During the war years the domestic production of casein was curtailed sharply, due to the greater use of skimmed milk in food products, but production has been increasing rapidly within recent months and the pre-war situation is probably the best basis for looking into the near future.

There are many established industrial uses for casein, the principal ones being in the sizing and coating of paper, in paints, in glues, and in the manufacture of plastics. During the last few years about 5 thousand tons have been used in the manufacture of fibers. Those who are familiar with the technology and economics of this industry are of the opinion that the production of casein might be doubled or even tripled if there were such a demand at a sufficient price. In even a moderate expansion of the demand for casein for use in fibers, however, the fiber industry would be in direct competition with other well established users of casein for a supply which is at present limited. Therefore, for any large-scale expansion, the protein fiber industry will have to find additional sources of protein.

Disregarding any technical problems involved, the three largest potential sources of industrial protein in this country, based on present production rates, are the vegetable seeds soybeans, cottonseed, and flaxseed, in that order. Large quantities of animal proteins are also obtainable from by-products of the packing houses and fishing industries, but the proteins obtained from these sources are already in full commercial use and only a very small percentage are of a quality suitable for making fibers. Hence, animal proteins will not be considered in this discussion as a large potential source of proteins for the production of synthetic fibers.

Oil is the product of principal value obtained from these seeds, and the price of oil is the main determinant of the prices paid to the growers. The cake and meal remaining after the oil is extracted is essentially a by-product. The protein content of this cake and meal ranges from about 35 percent for that obtained from flaxseed to about 40 percent in the case of soybeans and cottonseed.

During the past few years the production of soybean cake and meal has averaged about 3-1/2 million tons, cottonseed cake and meal slightly less than 2 million tons, and linseed cake and meal about 800 thousand tons, or an average total production from these three sources of about 6-1/4 million tons.

Another large potential source of industrial protein, based on present production rates, is peanuts, another oil-bearing seed. During the past few years the production of peanut cake and meal has averaged about 100 thousand tons annually, being obtained as a byproduct from the crushing of an average of about 200 thousand tons of peanuts annually for oil. The crushing of peanuts for oil on such a large scale is a comparatively recent development, receiving its greatest impetus during the war when there was a demand for oils far exceeding the supply. Prior to 1934, the only peanuts crushed for oil were those discarded at shelling plants as unfit for roasting, salting, or confectionary uses. From 1934 to the beginning of the war, peanut production was in excess of utilization by the usual trade outlets, but prices were maintained by means of various price support programs, and subsidy payments were made each crop year, except one, for the diversion of peanuts to crushers. In the crop year 1936-37, prices for peanut oil and meal were so high that crushers used large quantities of peanuts with subsidy payments. Subsidies in one form or another were continued until price ceilings on oils and meal were lifted a few months ago.

Whether peanuts will continue to be grown in large quantities for crushing will depend upon a number of factors, the principal one being future prices to the growers. A limiting factor in this connection is the fact that the price which crushers can pay for peanuts is closely determined by the prices for cottonseed and soybean oil and meal, with which peanut oil and meal compete. This price situation follows from the fact that peanut oil and meal comprise only a very minor part of the total markets for these products. Any attempt to predict the price of an agricultural commodity is a hazardous undertaking, so the influence of the factor of future prices to growers will have to be left as an unknown.

In any event, the potential supply of industrial protein from peanuts falls into about the same category as casein, both in regard to quantity and to the fact that protein fiber manufacturers would have to compete for their supplies with other industrial users of protein in a limited market. There would be this important difference, however: Every new supply of industrial protein placed on the market adds to the total supply of industrial protein, and competition between different sources of supply will rest more on the differences in the quality of the product.

As I indicated a moment ago, technical considerations have been disregarded in this discussion of potential sources of industrial protein for the manufacture of fibers. A brief discussion of these technical considerations will complete the picture.

The first technical consideration is the obtaining of a meal from which a satisfactory protein can be extracted, as has already been mentioned in connection with the research of the Southern Regional Research Laboratory on peanut-protein fibers. You will recall that the temperatures used in the hydraulic-press and screw-press processes are so high that the protein is damaged so far as most industrial uses are concerned, and that a higher percentage of oil than is desirable is left in the meal. You will recall also that the solvent extraction process provides a means of obtaining a meal from which a satisfactory industrial protein can be extracted.

Taking the foregoing potential sources of industrial protein in the order of their size, we find that solvent extraction is already in widespread use in the soybean industry, and that its use is still growing. Since a soybean-protein fiber with properties comparable to those of other protein fibers has already been manufactured on a semicommercial scale, it is probable that soybeans will be one of the sources of protein for fibers.

Cottonseed is the next largest potential source of industrial protein. Up until this year, all processing of cottonseed for oil has been done by the hydraulic-press and screw-press processes. However, three large plants have recently been completed for the solvent extraction of oil from cottonseed, and at least six others are either under construction or have been definitely planned. Those close to the cottonseed industry anticipate a steady growth in the use of solvent extraction for cottonseed, especially in areas of concentrated supplies of cottonseed. Of special importance in connection with this development, is the fact that the owners of many of these solvent extraction plants are also planning to process peanuts. Hence, it is probable that limited quantities of peanut meal will soon be available of a quality satisfactory for the extraction of industrial protein. In the case of cottonseed, there are still technical problems to be overcome in the production of a satisfactory protein fiber, the chief one arising from the fact that cottonseeds contain pigment glands which must first be removed. Research is now under way on this problem.

Practically all processing of flaxseed is now done by the screw-press process. One company has recently announced plans for a solvent extraction plant for flaxseed using a special process. However, the flaxseed industry has only recently been converted over from the hydraulic-press process, and it is not likely that any extensive conversion over to still another process will be undertaken for some time to come. As a consequence, it is not likely that flaxseed will figure prominently as a source of protein for synthetic fibers in the near future.

In summary, then, we find that in their present state of development, synthetic protein fibers of approximately comparable quality either have been, or can be, produced from a number of present and potential sources of industrial protein. Casein is the present largest source for the manufacture of protein fibers, but it is likely that soybean protein and peanut protein will also soon be used for this purpose. Peanuts by themselves could supply the protein for a moderate expansion of the protein fiber industry, but any really large-scale expansion would require additional sources of supply. As additional sources of industrial protein become commercially available, their relative use for the production of synthetic fibers will depend more and more upon their relative price and suitability, and upon technological developments in the production and properties of synthetic protein fibers.